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application environment. Circuit boards are constructed with submodules that allow the designer to tailor the hardware to the target applications. A typical submodule contains a 32-bit microprocessor and four megabytes of memory. Each board can accept up to eight submodules. Available processor modular functions include video frame grabbers, graphics display drivers, interface adapters, video processors, and MIL-STD-1553 and other system interfaces. Sensors accommodated include video, forward looking infra-red, and laser sensors.

The AR&D proof of concept demonstration simulation included as much hardware as possible and required real-time system operational capabilities that were provided by the Advanced Avionics System Development Lab. The docking vehicle and SSF dynamic models were contained in the main processor where the relative positions of the vehicles also were calculated as they orbit the earth. A docking vehicle view of the SSF is generated on a graphics monitor, which is viewed by a video sensor/IPA; an INU is mounted on a three-axis table to emulate the system's inertial sensors; and the loop is closed through the autopilot and dynamic model. System performance and status is monitored on graphic monitors or workstations. Three real-time parameters can be monitored on individual, autoranged graphs. Overall system performance is evaluated by freezing and displaying the velocity and displacement parameters at the instant of contact. A dedicated window displays the simulator's operational mode and configuration. Other windows display the orbital position and firings of the RCS jets. When docking with SSF, the docking vehicle must follow specific approach procedures. The simulated ELV approach started at a range of 300 meters behind the SSF, along its velocity vector, with approach to this point based on inertial and GPS references. Though the IPS can acquire and track the SSF from more than a kilometer, it is not the primary sensor until about the 20-meter range. Initially, the target was SSF. The target transition to the SSF docking module, then to the target on the docking module, and finally to the small target on the hatch of the docking module.

Expanded use of the simulator is planned for 1992. Areas to be explored will include sensor suite mix to add robustness, optimization of IPA configuration to support terminal guidance with collision avoidance, and evaluation of autolanding capabilities for terrestrial and planetary applications. The simulation facility will be used to help integrate the AR&D system into the NASA test facilities participating in the ARD&L System Test Program. The test program potentially will involve test facilities at JSC, MSFC, and LaRC to independently test and validate the performance of key elements of this pathfinder AR&D system.

Concerns addressed during the presentation: Is the use of the image processor discussed an overkill since only four dots were being viewed? Yes, for only that function. When growth considerations such as handling multiple targets, performing docking and supporting landing are considered, there is no overkill. What are the power requirements? 80 watts, but the system is flexible and can be reconfigured according to need.

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On-Orbit Demonstrations of Automated Closure and Capture Using ESA-Developed Proximity Operations Technologies and an Existing Serviceable NASA Explorer Platform Spacecraft

by Bill Hohweisner, Fairchild and
Jean-Michel Pairot, Matra Marconi Space

Since 1984 the European Space Agency (ESA) has been working to develop an autonomous rendezvous and docking capability to enable Hermes to dock automatically with Columbus. As a result, ESA (with Matra, MBB, and other space companies) have developed technologies that are directly supportive of the current NASA initiative for Automated Rendezvous and Capture. Fairchild and Matra would like to discuss the results of the applicable ESA/Matra rendezvous and capture developments and suggest how these capabilities could be used together with an existing

NASA Explorer Platform satellite to minimize new development and accomplish a cost-effective automatic closure and capture demonstration program.

Several RV sensors have been developed at breadboard level for the Hermes/Columbus program by Matra, MBB, and SAAB. For example, the Matra laser proximity operation sensor, developed with Matra and CNES funding is based upon a flight qualified CCD sensor working together with a pulsed laser to illuminate retroreflectors mounted on the target docking side. The CCD operates in a Flash-During-Transfer (FDT) mode, enabling operation even with sunlight in the sensor FOV. The sensor has demonstrated good results at ranges out to 1 km and at proximity operation relative velocities, even with the sun in the FOV. The sensor demonstrated recently at 10 m: range accuracy to 0.8% of range (3 sigma); elevation/azimuth accuracy better than 0.02° (3 sigma); and attitude angles of the target to better than 0.25° (3 sigma) using five optical retroreflectors in a 15 cm wide pattern.

Detailed algorithms for automatic rendezvous, closure, and capture have been developed by ESA and CNES for application with Hermes to Columbus rendezvous and docking. They currently are being verified with closed-loop software simulation. The algorithms have multiple closed-loop control modes and phases starting at long range using GPS navigation. Differential navigation is used for coast/continuous thrust homing, holdpoint acquisition, v-bar hopping, and station point acquisition. The proximity operation sensor is used for final closure and capture. A subset of these algorithms, comprising the proximity operations algorithms, could easily be extracted and tailored to a limited objective closure and capture flight demonstration.

The software to implement the automatic operations has been written in C and Ada. Closed loop performance tests are in progress. These tests include the software for final approach operations (100 m to a few cm), and testing is to be complete by January 1992.

Fairchild and Matra suggest that by combining ESA and NASA resources, a complementary, cost effective flight demonstration program to demonstrate automated closure and capture could be readily structured. This joint, cooperative program would use the automated guidance and proximity operations system developed by Matra for ESA and the existing, on-orbit Explorer Platform (EP) spacecraft developed by Fairchild for NASA. These two system elements would be integrated by Fairchild with an EP-mounted docking module receiver and a maneuvering payload module (PLM) to close with and dock to the EP docking module receiver.

The proposed program would have Fairchild build the docking module to be attached on-orbit to the EP, build the payload module with a maneuvering capability that performs the docking with the EP-attached docking module (using the Fairchild-developed resupply interface mechanism), complete development of the STS procedures for on-orbit EP payload changeout to remove the current EUVE payload and attach the docking module; and accomplish the overall system integration. European Space Agency and Matra would provide the proximity operations sensor and the guidance software as well as verify the satisfactory flight hardware closure and capture on the European Proximity Operations (EPOS) simulator and/or on the CNES 6 DOF Dynamic Docking Test Facility (DDTF).

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A Method for Modeling Contact Dynamics for Automated Capture Mechanisms

by Philip J. Williams, Logicon Control Dynamics Inc.

Logicon Control Dynamics develops contact dynamics models for space-based docking and berthing vehicles. The models compute contact forces for the physical contact between mating capture mechanism surfaces. Realistic simulation requires proportionality constants, for calculating contact forces, to approximate surface stiffness of contacting bodies. Proportionality

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